I claim:

1. An apparatus to measure emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a source of electromagnetic radiation adapted to irradiate a target sample;

means for generating first and second digital input signals of known frequencies with a known phase relationship;

means for converting said first and second digital input signals to analog sinusoidal signals;

means for directing said first input signal to said electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof to irradiate said target sample and generate a target sample emission;

means for detecting said target sample emission and producing a corresponding first output signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;

means for producing a known phase shift in said second input signal to create a second output signal;

means for converting said first and second analog output signals to digital signals;

a mixer for receiving said first and second digital output signals and comparing the signal phase relationship therebetween to produce a signal

digital output signal and generating an adjustment output signal therefrom, and means for varying the phase of said fifth digital signal based on said adjustment output signal to place said fifth digital signal and said first digital output signal in quadrature to determine the phase shift caused by the emission time delay of said targeted sample.

22. The apparatus as claimed in claim 20, wherein said signal generation means is adapted to create said first and second input signals with substantially the same frequencies and said third input signal with a substantially different frequency.

23. An apparatus to measure emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a source of electromagnetic radiation adapted to irradiate a target sample;

means for generating first and second digital input signals of known similar frequency and phase offset;

means for generating a third digital input signal having a frequency different from said first and second digital input signals;

means for converting said first, second and third digital input signals to analog sinusoidal signals;

means for directing said first input signal to said electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof to irradiate said target sample and generate a target sample emission;

means for detecting said target sample emission and producing a corresponding first intermediate signal having a phase shift relative to the

phase of said first input signal, said phase shift being caused by the irradiation time delay in said sample;

means for producing a known phase shift in said second input signal to create a second intermediate signal;

first signal down conversion means for combining the frequency of said third input signal with the frequency of said first intermediate signal to produce a first output signal representing the sum and difference frequencies between said first intermediate and said third input signals;

second signal down conversion means for combining the frequency of said third input signal with the frequency of said second intermediate signal to produce a second output signal representing the sum and difference frequencies between said second intermediate and said third input signals;

means for filtering out the sum frequency of each said first and second output signals;

means for converting said filtered first and second analog output signals to digital first and second output signals;

means for generating a fourth digital signal having a frequency the same as said second output signal;

means for mixing said second digital output signal with said fourth digital signal to create a feedback signal to said fourth signal generation means to adjust the phase of said fourth digital signal until it is in quadrature with said second digital output signal;

means for generating a fifth digital signal having a frequency substantially the same as said fourth digital signal;

means for mixing said fifth digital signal with said first digital output signal and generating an adjustment output signal therefrom; and

means for varying the phase of said fifth digital signal based on said adjustment output signal to place said fifth digital signal and said first digital output signal in quadrature to determine the phase shift caused by the emission time delay of said targeted sample.

24. The apparatus as claimed in claim 23, wherein said signal generation means is adapted to create said first and second input signals with substantially the same frequencies and said third input signal with a substantially different frequency than said first and second input signals.

25. The apparatus as claimed in claim 23, wherein said targeted sample comprises a fluorescent sample exposed to a light source modulated by said first input signal to cause said sample to generate fluorescence emissions having said phase shift.

26. The apparatus as claimed in claim 23, wherein said targeted sample comprises turbid media exposed to a light source modulated by said first input signal to cause said sample to emit time delayed scattered radiation having said phase shift.

27. An apparatus to measure emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a source of electromagnetic radiation adapted to irradiate a target sample;

means for generating first and second digital input signals of known frequencies with a known phase offset;

50

means for converting said first and second digital input signals to analog sinusoidal signals;

means for directing said first input signal to said electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof to irradiate said target sample and generate a target sample emission;

means for detecting said target sample emission and producing a corresponding first output signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;

means for producing a known phase shift in said second input signal to create a second output signal;

means for converting said first and second analog output signals to digital signals;

means for generating a third digital signal having a frequency the same as said second output signal;

means for mixing said second digital output signal with said third digital signal to create a feedback signal to said third signal generation means to adjust the phase of said third digital signal until it is in quadrature with said second digital output signal;

means for generating a fourth digital signal having a frequency substantially the same as said third digital signal;

means for mixing said fourth digital signal with said first digital output signal and generating an adjustment output signal therefrom; and

means for varying the phase of said fourth digital signal based on said adjustment output signal to place said fourth digital signal and said first digital

output signal in quadrature to determine the phase shift caused by the emission time delay of said targeted sample.

28. The apparatus as claimed in claim 27, wherein said targeted sample comprises a fluorescent sample exposed to a light source modulated by said first input signal to cause said sample to generate fluorescence emissions having said phase shift.

29. The apparatus as claimed in claim 27, wherein said targeted sample comprises a fluorescent sample exposed to a light source modulated by said first input signal to cause said sample to generate fluorescence emissions having said phase shift.

30. An apparatus to measure emission time delay in real time during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a single analog timing-base element to generate a digital clock signal;

a multiphase frequency generator synchronized to said digital clock signal;

means for converting outputs of said frequency generator into a first sample analog signal and a second reference analog signal, said converting means being synchronized to said digital clock signal;

means for generating known phase shift in said second reference analog signal;

means for generating unknown phase shift in said first analog signal by directing said first analog signal through said targeted sample;

means for converting phase shifted analog signal and reference signal into respective digital signals, said means synchronized to said analog timing element; and

means for comparing the phase of said first sample and said second reference digitized signals at quadrature in a digital mixer element, said mixer element being synchronized to said analog timing element.

8 7

~~31~~. The apparatus as claimed in claim ~~30~~, wherein said targeted sample comprises a fluorescent sample exposed to a light source modulated by said first sample analog signal to cause said sample to generate fluorescence emissions having said phase shift.

32. The apparatus as claimed in claim 30, wherein said ~~targeted sample~~ comprises a fluorescent sample ~~exposed to a light source~~ modulated by said first ~~sample~~ analog signal to cause said sample to generate fluorescence emissions having said phase shift.

9 7

~~33~~. The apparatus as claimed in claim ~~30~~, wherein said analog timing element comprises a crystal oscillator.

~~34~~. A method for measuring emission ~~time delay during the irradiation of~~ targeted samples by utilizing ~~digital signal~~ processing for determining the emission phase shift caused by irradiation of the sample, said method ~~comprising the steps of:~~

down converting said first signal by combining the frequency of said third input signal with the frequency of said first intermediate signal to produce a first output signal representing the sum and difference frequencies of said first intermediate and said third input signals;

producing a known phase shift in said second input signal to create a second intermediate signal;

down converting said second signal by combining the frequency of said third input signal with the frequency of said second intermediate signal to produce a second output signal representing the sum and difference frequencies of said second intermediate and said third input signals;

converting said first and second analog output signals to digital signals;

mixing said first and second digital output signals and comparing the signal phase relationship therebetween to produce a mixer signal indicative of the change in phase relationship between said first and second output signals caused by said target sample emission; and

simultaneously altering the frequencies of said first and second input signals while substantially continuously varying the phase offset between said first and second input signals based on said mixer signal and to alter the frequency of said third input signal to achieve desired downconversion frequency of said first and second output signals to ultimately place said first and second output signals in quadrature while compressing the frequency range therebetween.

40. A method for measuring emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the

emission phase shift caused by the sample, said method comprising the steps of:

generating first and second digital input signals of known frequencies with a known phase offset;

converting said first and second digital input signals to analog sinusoidal signals;

directing said first input signal to an electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof;

irradiating said target sample with the modulated emissions of said electromagnetic radiation source to generate a target sample emission;

detecting said target sample emission and producing a corresponding first output signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;

producing a known phase shift in said second input signal to create a second output signal;

converting said first and second analog output signals to digital signals;

generating a third digital signal having a frequency the same as said second output signal;

mixing said second digital output signal with said third digital signal to create a feedback signal to adjust the phase of said third digital signal until it is in quadrature with said second digital output signal;

generating a fourth digital signal having a frequency substantially the same as said third digital signal;

mixing said fourth digital signal with said first digital output signal and generating an adjustment output signal therefrom; and

varying the phase of said fourth digital signal based on said adjustment output signal to place said fourth digital signal and said first digital output signal in quadrature to determine the phase shift caused by the emission time delay of said targeted sample.

indicative of the change in phase relationship between said first and second output signals caused by said target sample emission; and

feedback means to alter the phase of the second input signal based on said mixer signal to ultimately place said first and second output signals in quadrature.

2. The apparatus as claimed in claim 1, wherein said feedback means simultaneously alters the frequencies of said first and second input signals while substantially continuously varies the phase offset between said first and second input signals based on said mixer signal to ultimately place said first and second digital output signals in quadrature while compressing the frequency range therebetween.

3. The apparatus as claimed in claim 2, wherein said signal generation means comprises a multiphase oscillator adapted to generate said input signals at specified frequencies and specified phases in response to said mixer signal.

4. The apparatus as claimed in claim 3, wherein said feedback means comprises a long pass filter for extracting and amplifying said mixer signal, and wherein said multiphase oscillator includes a frequency calculator for adjusting frequency of said input signals and a phase calculator for adjusting the relative phase said variable input signals.

5. The apparatus as claimed in claim 1, wherein said signal generation means is adapted to generate a third input signal, and wherein said apparatus

further comprises a first signal down conversion means positioned for combining the frequency of said third input signal with the frequency of said first analog output signal to produce a modified first output signal representing the sum and difference frequencies of said first output and said third input signals, and a second signal down conversion means positioned for combining the frequency of said third input signal with the frequency of said second analog output signal to produce a modified second output signal representing the sum and difference frequencies of said second output and said third input signals, said analog-to-digital conversion means converting said first and second modified output signals to digital signals.

6. The apparatus as claimed in claim 5, wherein said mixer includes means for filtering out the sum frequency of the first output and third input signals and the sum frequency of the second output and third input signals so that said analog-to-digital conversion means digitizes only the said difference frequencies of the output signals and said mixer compares the phase of only the difference frequency between the first output and third input signals with the difference frequency between the second output and third input signals.

7. The apparatus as claimed in claim 6, wherein said apparatus further comprises means for generating a fourth digital signal having a frequency the same as said second output signal, means for mixing said second digital output signal with said fourth digital signal to create a feedback signal to said fourth signal generation means to adjust the phase of said fourth digital signal until it is in quadrature with said second digital output signal, means for generating a fifth digital signal having a frequency substantially the same as

said fourth digital signal, means for mixing said fifth digital signal with said first digital output signal and generating an adjustment output signal therefrom, and means for varying the phase of said fifth digital signal based on said adjustment output signal to place said fifth digital signal and said first digital output signal in quadrature to determine the phase shift caused by the emission time delay of said targeted sample.

8. The apparatus as claimed in claim 7, wherein said signal generation means comprises a multiphase oscillator having a frequency calculator adapted to generate and adjust the frequencies of said first and second input signals and a phase calculator to adjust the phase of said second input signal in response to said mixer signal, and a second signal generation means to create said third input signal frequency, and wherein said feedback means comprises a low pass filter for extracting and amplifying said mixer signal and a second frequency calculator for adjusting the output of said second signal generation means.

9. The apparatus as claimed in claim 1, wherein said mixer comprises a phase demodulator, and said feedback means includes a low pass filter for extracting and amplifying said phase demodulator signal and a phase calculator for adjusting the phase of said second digital signal to ultimately place said first and second output signals in quadrature.

10. The apparatus as claimed in claim 1, wherein said targeted sample comprises a fluorescent sample exposed to a light source modulated by said

first input signal to cause said sample to generate fluorescence emissions having said phase shift.

11. The apparatus as claimed in claim 1, wherein said targeted sample comprises turbid media exposed to a light source modulated by said first input signal to cause said sample to emit time delayed scattered radiation having said phase shift.

12. An apparatus to measure emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a source of electromagnetic radiation adapted to irradiate a target sample;

means for generating first and second digital input signals of known frequencies with a known phase offset;

means for converting said first and second digital input signals to analog sinusoidal signals;

means for directing said first input signal to said electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof to irradiate said target sample and generate a target sample emission;

means for detecting said target sample emission and producing a corresponding first output signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;

means for producing a known phase shift in said second input signal to create a second output signal;

means for converting said first and second analog output signals to digital signals;

a mixer for receiving said first and second digital output signals and comparing the signal phase relationship therebetween to produce a signal indicative of the change in phase relationship between said first and second output signals caused by said target sample emission; and

feedback means to simultaneously alter the frequencies of said first and second input signals while substantially continuously varying the phase offset between said first and second input signals based on said mixer signal to ultimately place said first and second output signals in quadrature while compressing the frequency range therebetween.

13. The apparatus as claimed in claim 12, wherein said apparatus further comprises means for directing said first and second output signals individually through an antialiasing filter prior to said analog-to-digital conversion means.

14. The apparatus as claimed in claim 12, wherein said signal generation means comprises a multiphase oscillator adapted to generate said input signals at specified frequencies and to adjust the relative phase of said generated input signals in response to said mixer signal.

15. The apparatus as claimed in claim 14, wherein said feedback means further comprises a phase calculator adapted to receive said mixer signal and determine relative phase of input signals and a frequency calculator adapted to receive said mixer signal and determine frequency of said input signals.

16. The apparatus as claimed in claim 12, wherein targeted sample comprises a fluorescent sample exposed to a light source modulated by said first input signal to cause said sample to generate fluorescence emissions having said phase shift.

17. The apparatus as claimed in claim 12, wherein said targeted sample comprises turbid media exposed to a light source modulated by said first input signal to cause said sample to emit time delayed scattered radiation having said phase shift.

18. The apparatus as claimed in claim 12, wherein said signal generation means is adapted to generate a third input signal, and wherein said apparatus further comprises a first signal down conversion means positioned for combining the frequency of said third input signal with the frequency of said first output signal to produce a modified first output signal representing the sum and difference frequencies of said first output and said third input signals, and a second signal down conversion means positioned for combining the frequency of said third input signal with the frequency of said second output signal to produce a modified second output signal representing the sum and difference frequencies of said second output and said third input signals, said analog-to-digital conversion means converting said first and second modified output signals to digital signals for receipt by said mixer.

19. An apparatus to measure emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said apparatus comprising:

a source of electromagnetic radiation adapted to irradiate a target sample;

means for generating first, second and third digital input signals of known frequencies with known phase offsets;

means for converting said first, second and third digital input signals to analog sinusoidal signals;

means for directing said first input signal to said electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof to irradiate said target sample and generate a target sample emission;

means for detecting said target sample emission and producing a corresponding first intermediate signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;

first signal down conversion means for combining the frequency of said third input signal with the frequency of said first intermediate signal to produce a first output signal representing the sum and difference frequencies of said first intermediate and said third input signals;

means for producing a known phase shift in said second input signal to create a second intermediate signal;

second signal down conversion means for combining the frequency of said third input signal with the frequency of said second intermediate signal to produce a second output signal representing the sum and difference frequencies of said second intermediate and said third input signals;

means for converting said first and second analog output signals to digital signals;

a mixer for receiving said first and second digital output signals and comparing the signal phase relationship therebetween to produce a signal

indicative of the change in phase relationship between said first and second output signals caused by said target sample emission; and

feedback means to simultaneously alter the frequencies of said first and second input signals while substantially continuously varying the phase offset between said first and second input signals based on said mixer signal and to alter the frequency of said third input signal to achieve desired downconversion frequency of said first and second output signals to ultimately place said first and second output signals in quadrature while compressing the frequency range therebetween.

20. The apparatus as claimed in claim 19, wherein said mixer includes means for filtering out the sum frequency of said first intermediate and third input signals and the sum frequency of said second intermediate and third input signals to enable said analog-to-digital conversion means to digitize only the difference frequencies of said first and second output signals, said mixer comparing the phase of only the difference frequency between said first and second output signals.

21. The apparatus as claimed in claim 20, wherein said apparatus further comprises means for generating a fourth digital signal having a frequency the same as said second output signal, means for mixing said second digital output signal with said fourth digital signal to create a feedback signal to said fourth signal generation means to adjust the phase of said fourth digital signal until it is in quadrature with said second digital output signal, means for generating a fifth digital signal having a frequency substantially the same as said fourth digital signal, means for mixing said fifth digital signal with said first

generating first and second digital input signals of known frequencies having a known variable phase relationship;

converting said first and second digital input signals to analog sinusoidal signals;

directing said first input signal to an electromagnetic radiation source to modulate the emissions of said electromagnetic radiation source by the frequency thereof;

irradiating a target sample with the modulated emissions of said electromagnetic radiation source to generate a target sample emission;

detecting said target sample emission and producing a corresponding first output signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay of the emissions in said sample;

producing a known phase shift in said second input signal to create a second output signal;

converting said first and second analog output signals to digital signals;

mixing said first and second digital output signals and comparing the signal phase relationship therebetween to produce an error signal indicative of the change in phase relationship between said first and second output signals caused by said target sample emission; and

altering the phase of the second input signal based on said mixer signal to ultimately place said first and second output signals in quadrature.

35. The method as claimed in claim 34, wherein said mixer signal alters the frequencies of said first and second input signals while continuously varying the phase offset between said first and second input signals to

ultimately place said first and second digital output signals in quadrature while compressing the frequency range therebetween.

36. The method as claimed in claim 34, wherein said method further comprises the steps of generating a third input signal with said first and second input signals, down converting said first analog output signal by combining the frequency of said third input signal with the frequency of said first analog output signal to produce a modified first output signal representing the sum and difference frequencies between said first output and said third input signals, and down converting said second analog output signal by combining the frequency of said third input signal with the frequency of said second analog output signal to produce a modified second output signal representing the sum and difference frequencies between said second output and said third input signals, said first and second modified output signals being converted to digital signals

37. The method as claimed in claim 36, wherein the sum frequency of the first output and third input signals and the sum frequency of the second output and third input signals are filtered out so that only the difference frequency between the first output and third input signals is mixed and phase compared with the difference frequency between the second output and third input signals.

38. The method as claimed in claim 36, wherein method further comprises the step of generating a fourth digital signal having a frequency the same as said second output signal, mixing said second digital output signal with said

fourth digital signal to create a feedback signal to said fourth signal generation means to adjust the phase of said fourth digital signal until it is in quadrature with said second digital output signal, generating a fifth digital signal having a frequency substantially the same as said fourth digital signal, mixing said fifth digital signal with said first digital output signal to generate an adjustment output signal therefrom, and varying the phase of said fifth digital signal based on said adjustment output signal to place said fifth digital signal and said first digital output signal in quadrature to determine the phase shift caused by the irradiation of said targeted sample.

39. A method for measuring emission time delay during irradiation of targeted samples by utilizing digital signal processing to determine the emission phase shift caused by the sample, said method comprising the steps of:

generating first, second and third digital input signals of known frequencies with known phase offsets;

converting said first, second and third digital input signals to analog sinusoidal signals;

directing said first input signal to an electromagnetic radiation source to modulate said electromagnetic radiation source by the frequency thereof;

irradiating said target sample with the modulated emissions of said electromagnetic radiation source to generate a target sample emission;

detecting said target sample emission and producing a corresponding first intermediate signal having a phase shift relative to the phase of said first input signal, said phase shift being caused by the emission time delay in said sample;